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1. Title of the Invention:
Phased Array Antenna

2. Claim:

A phased array antenna comprising first and second antenna elements facing each other with a predetermined distance disposed therebetween, one or both of radio waves received by said antenna elements being phase shifted before adding them together, to thereby cause an output to be developed for a radio wave only from a predetermined direction, wherein there is provided an amplifier for amplifying the radio wave received by each of said antenna elements, prior to said adding.

3. Detailed Description:

This invention relates to a phased array antenna (phase difference feeding antenna) for use in receiving VHF waves.

A conventional antenna of this type is arranged as shown in FIGURE 1, for example, and includes a forward antenna element 1 and a rearward antenna element 2. An induced voltage from the forward antenna element 1 is applied to a phase shifter 3, and an induced voltage from the rearward antenna element 2 and the voltage through the phase shifter 3 are added together in an adder 4.

Let it be assumed that a radio wave from the forward direction as absorbed by the forward antenna 1 is a radio wave "a", a radio wave from the forward direction as absorbed by the rearward antenna 2 is a radio wave "a'", a radio wave from the rearward direction as absorbed by the rearward antenna 2 is a radio wave "b", a radio wave from the rearward direction as absorbed by the forward antenna a is a radio wave "b'", and the distance ℓ between the forward and rearward antennas 1 and 2 is such as to provide a time lag of $x \cdot \lambda$ where $0<x<½$.

The amount of phase to be shifted by the phase shifter 3 is determined to be $(½ - x) \cdot \lambda$.

When "a" = sin (ω_1t), the wave a" developed by the phase shifter 3 is expressed as,

$a"=\sin\{\omega_1 t - (\frac{1}{2} - x) \cdot \lambda\}$, and

the wave a' is expressed as,

$a'=\sin(\omega_1 t - x \cdot \lambda)$.

Accordingly, the output A of the adder 4 is:

$A = a' + A" = 2 \sin (\omega_1 t - \frac{1}{4}\lambda) \cdot \cos (x\lambda - \frac{1}{4}\lambda)$

Similarly, when $b = \sin (\omega_2 t)$, the output B of the phase shifter 4 is:

$B = b + b" = 2 \sin (\omega_2 t - \frac{1}{4}\lambda) \cdot \cos \frac{1}{4}\lambda = 0$.

Ideally, the wave B from the rearward direction is not received. In other words, the antenna of FIGURE 1 exhibits single directivity as shown in FIGURE 2.

The prior art phased array antenna shown in FIGURE 1 is arranged as a common passive antenna. Therefore, loss in the phase shifter and the adder directly leads to decrease of the sensitivity of the antenna, resulting in sensitivity (from −2 dB to 6 dB), which is lower than the sensitivity of standard dipole antennas, for all that it is a two-element antenna. This loss cannot be improved even when amplifying means, such as an antenna booster, is disposed in a stage succeeding the adder.

An object of this invention, therefore, is to provide a high-sensitivity phase difference feeding antenna.

For that purpose, there are provided amplifiers which amplify the radio waves received by the respective antenna elements before adding them in an adder.

Hereinafter, the invention is described in detail with reference to embodiments shown in FIGURES 3 through 5.

FIGURE 3 is a plan view of an antenna according to one embodiment of the invention. Two, first and second, antenna elements 10 and 10' are supported on antenna bases 11 and 11' in such a manner as to be spaced apart by a predetermined distance from each other. Each of the antenna elements includes two half-wavelength folded elements and is arranged to be a horizontal dipole-type antenna.

Radio waves received by the antenna elements 10 and 10' are amplified by amplifiers 12 and 12', respectively, whose outputs, in turn, are applied to an adder 14 via phase shifters 13 and 13', respectively, and added together therein.

The phase shifters 13 and 13' are arranged to provide different amounts of phase shift to the signal passing therethrough. The amount of phase shift provided by one phase shifter 13' may be zero. The output of the adder 14 is sent out from an output terminal 15 as an input to a front end of a receiver.

In order for the antenna with the above-described arrangement to exhibit directivity similar to the one of the antenna of FIGURE 1 shown in FIGURE 2, for radio waves coming from the directions A and B, the amounts of phase shift provided by the phase shifters 13 and 13' are so adjusted that the radio waves from the direction B to be added in the adder 14 can have a phase difference of 180° and can be opposite in phase.

By amplifying the radio waves received by the antenna elements in the amplifier 12 and 12' before applying them to the adder 14, as described above, the antenna sensitivity becomes subject to the SN ratio of the outputs of the amplifiers 12 and 12', and the loss caused due to the phase shifters 13 and 13' and the adder 14 can be substantially negligible. Accordingly, by employing low noise generating components as components of the amplifiers 12 and 12', a high-sensitivity phased array antenna can be realized. Loss which would be generated by a cable extending from the output terminal 15 to the receiver is also negligible.

FIGURE 4 shows another embodiment according to which an antenna receiving section is formed as a small-sized tuned type. Each of antenna elements 100 and 100' are formed of two small-sized elements exhibiting capacitiveness to frequencies in a receiving band, and the length of the signal receiving section is from about λ/8 to about λ/12.

Radio waves received by the antenna elements 100 and 100' are applied through tuning units 101 and 101', respectively, to amplifiers 102 and 102'. Outputs from the amplifiers 102 and 102' are applied through phase shifters 103 and 103', respectively, to an adder 104. A signal resulting from the addition in the adder 104 is sent to a front end of a receiver through an output terminal 105.

FIGURE 5 shows a specific example of the structure of the tuning unit 101 and amplifier 102 shown in FIGURE 4. In the illustrated example, the tuning unit 101 is arranged to perform impedance transformation as well as tuning, and the transformer 102 is arranged to perform amplification and also balance-unbalance transformation. Although only components associated with

the antenna element 100 are shown, the tuning unit 101' and amplifier 102' have the same structures.

As shown in detail in FIGURE 5, a variable tuning circuit 101 including a variable reactance element is connected to the output of the antenna element 100, and the impedance of the tuning circuit 101 is designed to exhibit inductiveness to frequencies in the receiving band. The amplifier 102 including an active element is connected to the output of the tuning circuit 101, and amplifies an antenna receiving signal for realizing high-sensitivity signal reception.

The antenna element 100, the variable tuning circuit 101 and the amplifier 102 are arranged to be a unit to provide what is called an active antenna device. Accordingly, the electrical connection between the antenna element 100 and the tuning circuit 101 can be significantly short, which means that a reactance component provided by a connecting cable can be neglected. Then, even when the capacitive antenna element 100 is formed to be sufficiently small, the reactance of the tuning circuit can be made capacitive for all the frequencies over the receiving band by adjusting the reactance of the variable tuning circuit 101, whereby the capacitive reactance of the antenna element and the inductive reactance of the tuning circuit can be cancelled out to tune over the entire receiving band.

Specifically, the variable tuning circuit has a parallel resonant circuit configuration including an inductance coil L, a variable capacitor VC as a variable reactance element, and capacitors C_1, C_2 and C_3, and is used also for the dipole antenna forming the antenna element 100. This circuit provides impedance transformation in accordance with the ratios in capacitance between C_1 and C_2 and between C_2 and C_3, and also acts to transform the impedance of each antenna to the input impedance of the amplifier 102. The variable capacitor VC may be arranged to be operable together with the tuning of the receiver.

The amplifier 102 includes two dual-gate MOS transistors Q_1 and Q_2. Outputs from the node of the capacitors C_1 and C_2 and the node of the capacitors C_2 and C_3 are coupled to the first gates of the transistors Q_1 and Q_2. A constant voltage is applied to the second gates of the transistors Q_1 and Q_2 from a voltage source E. Outputs at the drains of the transistors Q_1 and Q_2 are coupled to respective ones of opposite ends of a coil L_1 of a transformer T. A secondary

coil L_2 is coupled to the coil L_1, and an unbalanced output is derived from the coil L_2. The transformer T acts as a balance-unbalance transformer. There are also provided a +B voltage supply terminal 102a and an output terminal 102b.

As described above, according to this invention, radio waves received by the respective antenna elements are amplified before they are added together, and, therefore, the radio waves are placed to higher levels before being subjected to loss caused by phase shifters and an adder. Accordingly, the loss occurring in stages subsequent to the amplifiers can be substantially negligible when low-noise components are used in the amplifier. Thus, a high-sensitivity phased array antenna (phase difference feeding antenna) can be realized.

As in the illustrated embodiment, by adding tuning circuits to the receiving section provided by an antenna element and by making the tuning circuit operable together with the receiver, the antenna elements can be down-sized to about one-third of prior art elements with an equivalent sensitivity maintained. Thus, the antenna can be suitable to be used as an indoor antenna for receiving FM broadcast signals.

4. Brief Description of the Drawings:

FIGURE 1 is a block diagram illustrating the principle of a prior art phased array antenna; FIGURE 2 is a graph showing the directivity of the antenna of FIGURE 1; FIGURE 3 is a plan view of a phased array antenna according to one embodiment of the invention; FIGURE 4 is a block diagram of an antenna according to another embodiment; and FIGURE 5 is a circuit diagram specifically showing part of the antenna of FIGURE 4.

10, 10'; 100, 100':	Antenna Elements
12, 12'; 102, 102':	Amplifiers
13, 13'; 103, 103':	Phase Shifters
14, 104:	Adder